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Systematic Review

Tai Ji on Cognitive Function Improvement in Parkinson's Disease: A Meta-Analysis

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Abstract

Background: Tai Ji (TJ) can improve cognitive function, which in turn brings life quality to Parkinson's disease (PD) patients. Cognitive function is thus important for PD patients. Analyzing the cognitive function and obtaining precise TJ exercise prescriptions are effective in treating PD patients. **Objectives**: The purpose of this review was to discuss the current Randomized Controlled Trials (RCTs) of TJ and cognitive function improvement in PD. **Materials and Methods**: Databases, including PubMed, Web of Science, Scopus, Cochrane Library, EBSCOhost, Wan Fang, and CNKI, were searched. Cochrane systematic evaluation method was adopted wherein 6 RCTs met the final inclusion criteria. **Results**: Among the 6 included RCTs, 3 were of high quality, and the rest were of medium quality. Quantitative analysis exhibited that TJ intervention improved the cognitive function of PD patients. TJ promoted the global cognitive function ($p < 0.05$) and the executive function ($p = 0.09$) compared with the control. However there was no significant improvement in cognitive motor. TJ training intervention doses of two times a week with 45–60 min sessions over $\leq$12 weeks could improve the cognitive function of PD patients. **Conclusions**: TJ affects the cognitive function of PD patients. However, this effect may have a reduced or no significant impact as the disease increases. PD patients can choose TJ as an intervention for 45–60 min twice a week for at least 12 weeks to accomplish maximum improvement in cognitive function.

Keywords: cognitive function; Tai Ji; Parkinson's disease; meta-analysis

1. Introduction

Parkinson's disease (PD) is one of the most prevalent neurodegenerative conditions which affects 1% of people worldwide of over 55 years of age and is characterized by movement slowness (bradykinesia), muscular stiffness, and rest tremors [1,2]. A range of non-motor symptoms (NMS) related to the condition is experienced by PD patients [3] along with essential motor components [4]. Debilitating NMS, such as sleep disruption, cognitive decline, and depression, are present in a large number of PD patients. Recent studies demonstrated NMS being present in the entire course of PD and affecting patient's life quality [5,6]. One common effect of PD is cognitive decline [7]. Physical activity improves cognitive function and delays cognitive deterioration in PD patients [8]. Research supporting the positive impact of non-pharmacological therapy is expanding [9].

Tai Ji (TJ) is a popular mind-body intervention that tackles a variety of motor and NMS associated with PD [10]. TJ is multi-faceted, having benefits for physical and mental health. It blends meditation with slow movements to relieve stress, improve mood, develop flexibility, and enhance the balance [11–13]. A large-scale randomized investigation by Li *et al.* [14] in 2012 revealed that TJ outperformed weight training and stretching, regarding improvement in balance impairments, increasing functional ability, and reducing falls. TJ lowers stress and improves life quality and motor performance [15]. TJ effects on non-motor outcomes in PD have been less focused [16]. No meta-analyses have examined the PD patients' cognitive performance which is linked to the overall life quality [17].

The purpose of this study was to combine TJ randomized controlled trials (RCTs) to evaluate the TJ's impact on PD patients' ability to improve cognitive function. It also covered surveys of exercise doses and the progress of interventions. It was expected that TJ had a considerable advantage over the control group in enhancing the cognitive performance of PD patients and had an impact on cognitive subdomains.

2. Material and Methods

2.1 Search Strategy

This meta-analysis was conducted and reported in accordance with PRISMA principles [18]. Up to 19th December 2022, Jinling Y. and Yang L. made literature search from WBM, CNKI, PubMed, Web of Science (WOS), Scopus, Cochrane Library, and EBSCOhost databases by using the Boolean search technique, phrases and fields specific to the database (Appendix Table 3). For instance, the PubMed search string was: [title/abstract] [("Parkinson disease"

Table 1. Reported clinical trials of Tai Ji in Parkinson's disease patients (from older to newer publications).

References (first author)	Mean age (years)	Size (Sex: M/F)	Disease duration (years)	Hoehn-Yahr	Means of intervention		Intervention dose (treatment group)	Outcomes
					Intervention group	Control group		
Hackney [21] (2009)	T: 64.9 ± 2.3 C: 66.8 ± 2.4	T: 13 (M/F: 11/2) C: 17 (M/F: 11/6)	T: 8.7 ± 1.3 C: 9.2 ± 1.4	T: 2.0 ± 0.1 C: 2.0 ± 0.2	Yang Short Style Tai Ji	Waltz/Foxtrot	60 min session, 2 sessions per week for 10–13 weeks	PDQ-39
	T: 64.9 ± 2.3 C: 68.2 ± 1.4	T: 13 (M/F: 11/2) C: 14 (M/F: 11/3)	T: 8.7 ± 1.3 C: 6.9 ± 1.3	T: 2.0 ± 0.1 C: 2.1 ± 0.1		Tango		
	T: 64.9 ± 2.3 C: 66.5 ± 2.8	T: 13 (M/F: 11/2) C: 17 (M/F: 12/5)	T: 8.7 ± 1.3 C: 5.9 ± 1.0	T: 2.0 ± 0.1 C: 2.2 ± 0.2		No Intervention		
Dong-Won [22] (2011)	T: 67.00 ± 9.13 C: 66.53 ± 10.35	T: 15 (M/F: 7/8) C: 15 (M/F: 6/9)	T: 7.17 ± 6.09 C: 5.91 ± 2.95	T: 2–2.5 C: 2–3	Tai Ji	No Intervention	30–40 min session, one session per week at clinic and three times per weeks at home for 8 weeks	K-MMSE (cognition)
Nocera [23] (2013)	T: 66 ± 11 C: 65 ± 7	T: 15 (M/F: 7/8) C: 6 (M/F: 4/2)	T: 8.08 ± 5.42 C: 6.83 ± 1.83	T: 2–3 C: 2–3	Yang Short Style Tai Ji	No Intervention	60 min session, three times per week for 16 weeks	PDQ-39; Trails A and B; Letter Verbal Fluency; Category Verbal Fluency; Stroop Color Word Test; Digit Span Backward
Xihong Guan [24] (2016)	T: 69.52 ± 5.23 C: 69.61 ± 5.16	T: 30 (M/F: 14/16) C: 30 (M/F: 17/13)	T: 3.46 ± 1.04 C: 3.23 ± 1.12	T: 2.04 ± 0.53 C: 2.14 ± 0.42	Tai Ji	No Intervention	60 min session, four times per week for 12 weeks	MoCA
Tingting Wu [25] (2018)	T: 62.42 ± 5. 37 C: 64.66 ± 5.47	T: 28 (M/F: 20/8) C: 24 (M/F: 17/7)	T: 4.75 ± 2. 01 C: 4.25 ± 1.96	T: 1–3 C: 1–3	Tai Ji	No Intervention	40 min session, four times per week for 16 weeks	MoCA
Vergara-Diaz [26] (2018)	T: 65.7 ± 3.86 C: 62 ± 7.77	T: 15 C: 12	T: 2.9 ± 2.38 C: 2.9 ± 2.20	T: 2–2.5 C: 2–2.5	Tai Ji	Usual healthcare	60 min session, one session per week at home and two times per week at clinic for 24 weeks	TMT; DTc; DTs; Gait speed DTc; Gait speed DTs

Abbreviations: M/F, Male/Female; PDQ-39, Parkinson's Disease Questionnaire 39; K-MMSE, Korean Version of Mini Mental Status Examination; MoCA, Montreal Cognitive Assessment; TMT, Trail Making Test; DT, Dual-task; DTc, counting backwards by 3s; DTs, the Star Movement Task; T, treatment group; C, control group.

Note: Executive function: Trails A and B, Letter Verbal Fluency, Category Verbal Fluency, Stroop Color Word Test, Digit Span Backward. Cognitive motor: DTc, DTs, Gait speed DTc, Gait speed DTs. Global cognitive: MoCA, K-MMSE, PDQ-39.

[MeSH])] AND ("Tai Ji"[MeSH]) AND ("cognition"[MeSH] OR "cognitive behavioral") AND ("randomized controlled trial"[MeSH]).

2.2 Inclusion and Exclusion Criteria

The inclusion and exclusion criteria for the designed study were as follows: (i) Participants: people with PD and no other primary disease; (ii) Intervention and comparison: studies comparing TJ interventions with active and inactive controls were included; studies where TJ was specified as control condition or TJ combined with other practices or exercise forms were excluded; (iii) Outcomes: any data assessing the cognitive function; (iv) Study type: studies with randomized controlled trials (RCTs) were included.

2.3 Study Selection

Titles and abstracts were used to filter distinct items (after removing duplicates) retrieved from electronic bibliographic database searches for inclusion. The searched literature was vetted based on inclusion and exclusion criteria. JY and YL organized and executed the research project, designed and executed statistical analysis. WL, conception and organization of research project. YF, conception of research project. Additional papers were regarded as complementary but used in the data collection process. Text reporting the most comprehensive data was chosen as the main text.

2.4 Quality Assessment and Bias Risk

The searches used the article quality assessment criteria manual recommended by Cochrane Manual 5.1.0 to assess the quality of included literature [19] and evaluated each sub-item as "low risk", "unclear" and "high risk".

2.5 Data Extraction

The two studies extracted the following information: first author, publication year, sample size, age, disease severity, intervention method, intervention dose, and outcome. The methods used to test various cognitive functions in humans were divided into executive function, global cognition, and cognitive motor [20].

2.6 Data Analysis

Forest maps were plotted for included publications using Review Manager 5.3 (RevMan 5.3, The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark), and the calculated effect sizes were analyzed through standardized mean differences (SMD). The fixed-effects and random-effects models' 95% confidence intervals (95% CI) were estimated. I^2 was the main indicator of heterogeneity; If I^2 was $<50\%$, the heterogeneity could be ignored, and a fixed-effect model was applied; if I^2 was between 50% and 75%, heterogeneity was moderate; and if I^2 was $>75\%$, the random effect model was applied, and heterogeneity causes were discussed and analyzed. SMD ≥ 0.2 was the modest, ≥ 0.5 was medium, and ≥ 0.8 was large when calculating the effect size. A significant impact was considered with $p < 0.05$.

3. Results

3.1 Study Identification and Selection

The databases yielded a total of 43 articles, where 16 were excluded before screening. Thirteen articles were disregarded after reading the titles and abstracts. The remaining 14 were required to be read in their entirety. One article was not retrieved. Seven articles were excluded because of too low quality (n = 2), TJ intervention present in both experimental and control groups (n = 1), outcome indexes did not mention cognitive component (n = 2), and the outcome data unavailable (n = 2). The remaining 6 articles were quantitatively synthesized and analyzed (Fig. 1).

3.2 Study Characteristics

The characteristics of included studies were summarized in Table 1, where 6 RCTs [21–26] were included in this study. 116 participants (experimental group) completed TJ training, and 135 underwent other training forms, usual healthcare, or no intervention as a control group. The age ranged from 62 to 70 years. The studied number of subjects varied from 21 [23] to 60 [24]. Most studies had a higher ratio of men to women [21,23–25] except one study with a higher ratio of women [22] and one study did not mention this ratio [26]. In most studies, the participants had disease duration of ~8 years [21–23], few ~4 years [24,25], and the shortest was ~3 years [26]. Studies presented participants' baseline PD ratings in the same way (Hoehn-Yahr) between 1 and 3. Intervention doses ranged 2–4 times per week, with each lasting 30 to 60 min and the common duration being 60 min [21,23,24,26]. Total intervention time varied from 8 [22] to 24 weeks [26]. In outcomes, most studies used scale reflecting cognition (Parkinson's Disease Questionnaire 39 (PDQ-39) [21,23], Korean Version of Mini Mental Status Examination, K-MMSE [22], Montreal Cognitive Assessment (MoCA) [24,25]), while few employed executive function measures [23,26].

3.3 Quality Assessment

Five studies (83.3%) reported the random sequence generation methods. Four (66.7%) mentioned the allocation concealment techniques. Three (50%) managed to blind the subjects and staff. They thus had low bias risk because of assessors' blinding. Regarding bias reporting, every study reported the anticipated findings. The majority of studies lacked a description of additional bias risks. Three studies (50%) were of excellent quality providing an overview of 6 RCTs' quality ratings. A quality assessment summary of 6 RCTs was presented in Figs. 2,3.

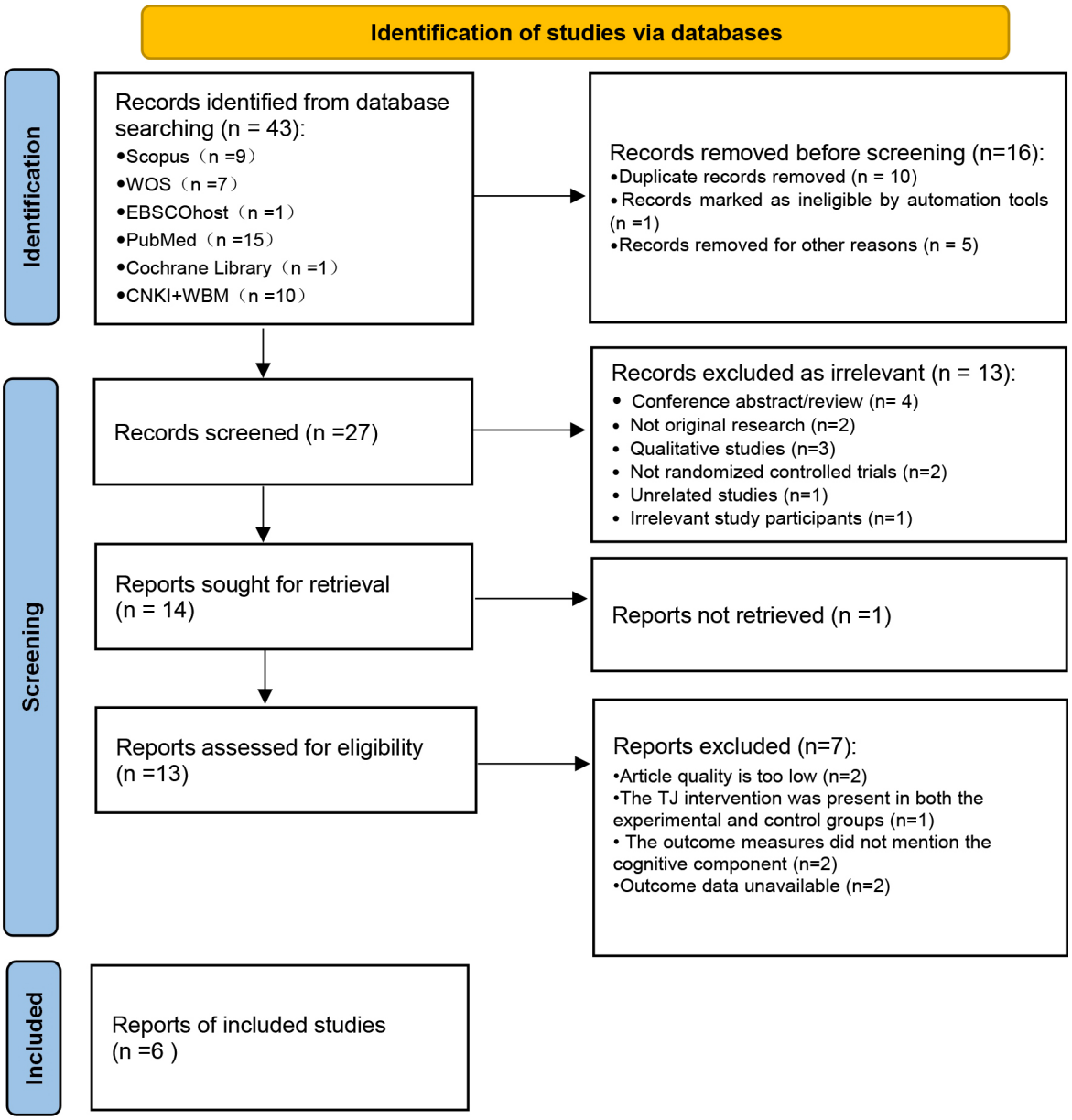

Fig. 1. Flow diagram summarizing the literature search strategy.

3.4 Meta-Analysis of TJ on Cognitive Function Improvement in PD

3.4.1 Effect of TJ on Overall Cognitive Function

All RCTs studied TJ's impact on PD patients' cognitive function. The random effect model was employed as the results were statistically significant ($p < 0.00001$, $I^2 = 82\%$; SMD = 0.64, 95% CI (0.21, 1.07), $p = 0.003$) (Fig. 4a).

3.4.2 Effect of TJ Executive Function

RCTs [23,26] examined the TJ effect on executive function in PD. Results were not statistically significant [SMD = 0.25, 95% CI (–0.04, 0.54), $p = 0.09$], and a fixed-effect model ($p = 0.94$, $I^2 = 0\%$) was adopted (Fig. 4b).

3.4.3 Effect of TJ Cognitive Motor

One RCT [26] examined the TJ effect on the improvement of cognitive motor in PD. Results were not statistically significant [SMD = –0.26, 95 CI% (–0.65, 0.13), $p = 0.19$] and employed a fixed-effect model ($p = 0.18$, $I^2 = 38\%$) (Fig. 4c).

3.4.4 Effect of TJ Global Cognition

Five RCTs [21–25] examined TJ impact on global cognition in PD. Results were statistically significant [SMD = 1.65, 95% CI (0.83, 2.48), $p < 0.0001$], wherein the random-effect model was adopted ($p < 0.00001$, $I^2 = 86\%$) (Fig. 4d).

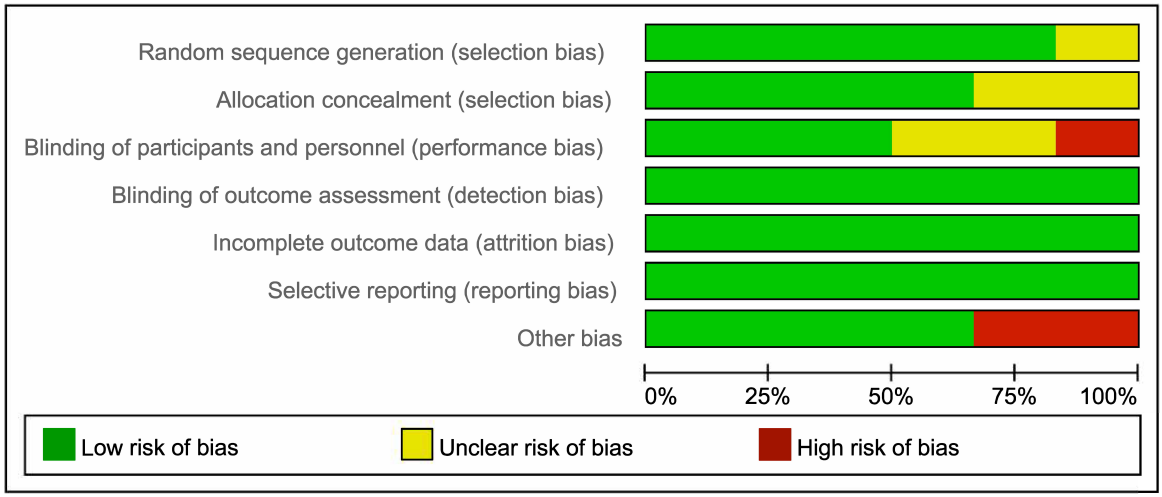

Fig. 2. The bias risk for included studies.

Table 2. Subgroup analysis of TJ on cognitive function improvement in PD.

Sectionalization			Number of researchers	Effectiveness	95% confidence interval (CI)	Effect on *p* values	Heterogeneity (I^2, *p*)
Disease duration		<4 year	2	2.38	[1.32, 3.45]	<0.0001	92.8%, 0.0002
		>7 year	4	0.25	[–0.08, 0.59]	0.14	
Intervention dose	Frequency	2 times/week	1	2.81	[1.96, 3.66]	<0.00001	95.5%, <0.00001
		3 times/week	2	0.05	[–017, 0.27]	0.66	
		4 times/week	3	1.20	[0.52, 1.89]	0.0006	
	Duration	≤12 weeks	3	2.21	[1.45, 2.97]	<0.00001	96.2%, <0.00001
		≥16 weeks	3	0.13	[–0.10, 0.36]	0.26	

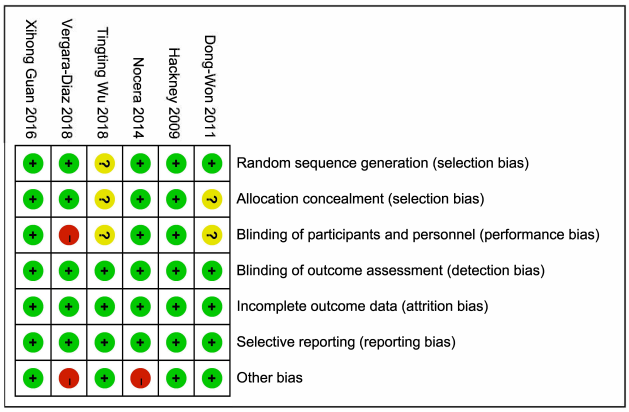

Fig. 3. Bias risk summary: authors' judgments about each bias risk item for included studies.

3.5 Subgroup Analysis

Disease duration: In the disease duration subgroup analysis (Table 2). TJ had the greatest impact on improving cognitive function in PD patients having the disease of <4 years [SMD = 2.38, 95% CI (1.32, 3.45), $p < 0.0001$]. There was no significant difference in PD patients with a disease of >7 years [SMD = 0.25, 95% CI (–0.08, 0.59), $p = 0.14$].

Intervention dose: The subgroup analysis results for exercise frequency of intervention doses depicted that two TJ interventions per week were the most conducive [SMD = 2.81, 95% CI (1.96, 3.66), $p < 0.00001$]. Three TJ interventions per week decreased [SMD = 0.49, 95% CI (0.52, 1.89), $p = 0.0006$], while four did not significantly improve the cognitive function in PD patients ($p = 0.66$). The effect of intervention lasting longer than 12 weeks was the largest [SMD = 2.21, 95% CI (1.45, 2.97), $p < 0.00001$], while TJ interventions of more than 16 weeks did not significantly improve the cognitive function in PD patients ($p = 0.26$).

4. Discussion

4.1 Summary of Findings

A meta-analysis of 6 RCTs was performed with 251 participants. The findings revealed that TJ led to cognition improvements (overall cognitive function, $p < 0.05$). TJ training also improved the global cognitive function ($p < 0.05$) and executive function ($p = 0.09$) compared with control. However there was no significant improvement of cognitive motor. In subgroup analysis, TJ training improved cognitive function in PD patients with a disease duration of <4 years, while there was slight improvement with a disease duration >7 years which was not statistically significant. For TJ training intervention, doses of two times per

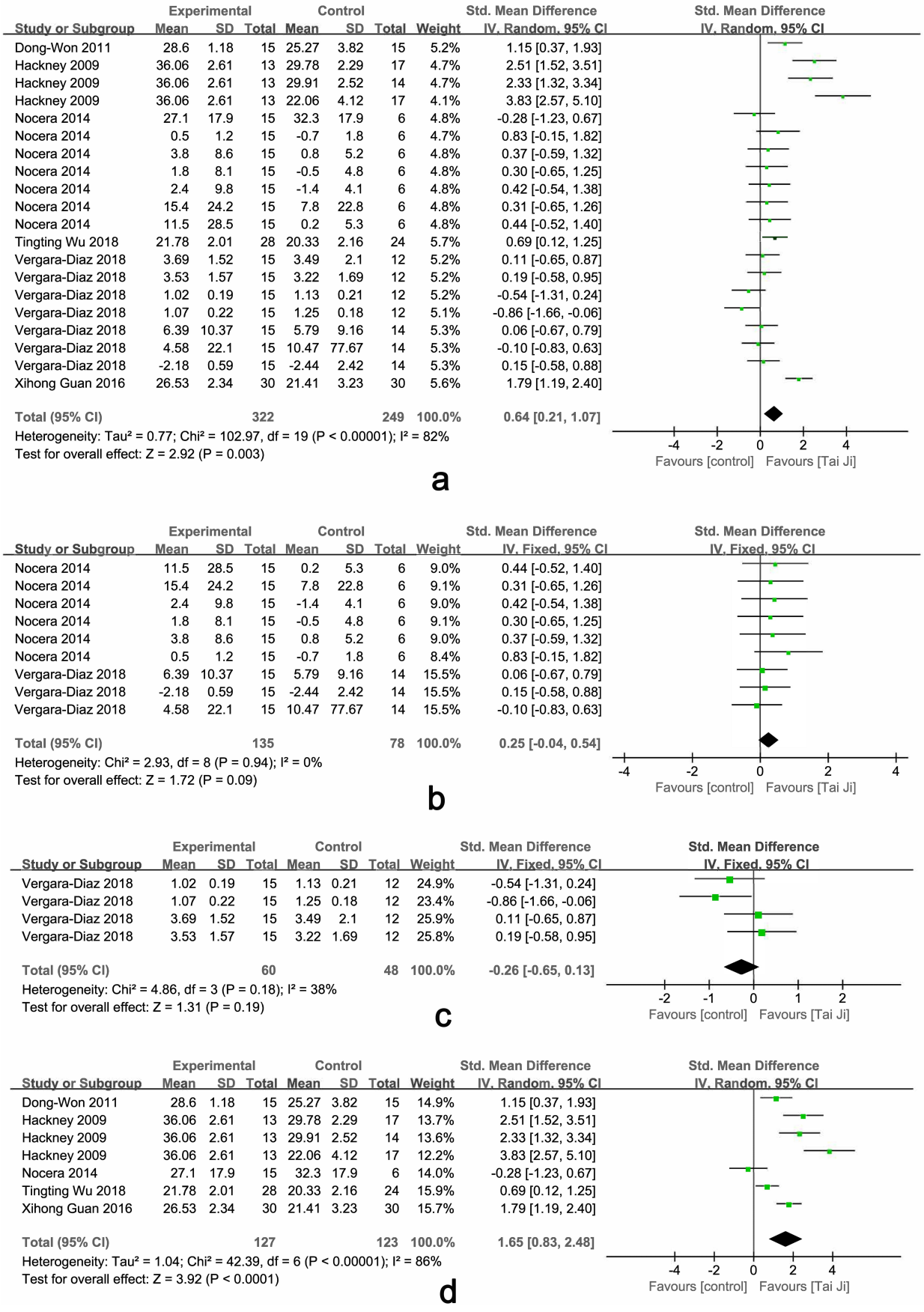

Fig. 4. Meta-analysis of TJ on Cognitive Function Improvement in PD. (a) Overall cognitive function. (b) Executive function. (c) Cognitive motor; and (d) global cognition.

Table 3. Searching strategy in Database.

Database	Search strategy	Results
PubMed	#1-All Fieldes: "Parkinson disease" OR "Idiopathic Parkinson's Disease" OR "Lewy Body Parkinson's Disease" OR "Parkinson's Disease, Idiopathic" OR "Parkinson's Disease, Lewy Body" OR "Parkinson Disease, Idiopathic" OR "Parkinson's Disease" OR "Idiopathic Parkinson Disease" OR "Lewy Body Parkinson Disease" OR "Primary Parkinsonism" OR "Parkinsonism, Primary" OR "Paralysis Agitans" OR "Parkinson's disease" #2-All Fieldes: "Tai Ji" OR Tai-ji OR "Tai Chi" OR "Chi, Tai" OR "Tai Ji Quan" OR "Ji Quan, Tai" OR "Quan, Tai Ji" OR Taiji OR Taijiquan OR "T'ai Chi" OR "Tai Chi Chuan" #3-All Fieldes: "cognition" OR "cognitions" OR "cognitive function" OR "cognitive functions" OR "function, cognitive" OR "functions, cognitive"	15
Web of Science	((Topic (TS)=(Parkinson disease)) AND TS=(tai ji)) AND TS=(cognition)	7
Scopus	TITLE-ABS-KEY ("Parkinson disease") AND TITLE-ABS-KEY ("tai ji") AND TITLE-ABS-KEY (cognition)	9
Cochrane Library	#1 MeSH descriptor: [Parkinson Disease] explode all trees #2 MeSH descriptor: [Tai Ji] explode all trees #3 MeSH descriptor: [Cognition] explode all trees #4 #1 ADN #2 AND #3	1
EBSCOhost	TI: "Parkinson Disease" AND TX: "tai ji" AND TX: cognition	1
WBM (Chinese Database)	Title and keywords: tai ji AND Title and keywords: Parkinson Disease AND Title and keywords: cognition	2
CNKI (Chinese Database)	Topic:Parkinson Disease AND Topic:tai ji AND Topic:cognition	8

week with 45–60 min sessions over $\leq$12 weeks improved the cognitive function of PD, and other training dose modes had obvious but small effects.

4.2 TJ and Cognitive Function

TJ training, compared to control, enhanced cognitive function of PD patients as per this meta-analysis. This was consistent with the findings of Horstink M *et al.* [27] that TJ training enhanced cognitive function in both normal cognitive function and cognitive impairment. TJ delayed cognitive decline in moderate PD patients. Previous studies revealed that physical activity interventions improved cognitive function in adults regardless of their cognitive status, and TJ significantly improved cognitive function [28–31]. This study summarized TJ effectiveness in PD patients of various degrees, providing a theoretical foundation for precise exercise prescriptions.

The vital part of a person's cognition is executive function. These results initially suggested that TJ might not be the best treatment for enhancing the cognitive executive function of PD patients ($p < 0.1$). The brain frontal lobe was recognized for controlling tasks like memory renewal, attention switching, and multi-task coordination, but the executive function was higher cognitive activity connected to it [32]. The prefrontal, parietal, and temporal lobes of the brain could modify their form and function [33]. TJ training as moderate-intensity aerobic exercise thus improved people's executive function. Considering that one study was included [23], there was a trend of significant differences in outcomes, although not significant. The hypothesis that TJ training improved executive function in PD patients would be clearly demonstrated if more RCTs were analyzed.

Dual tasks were used for the outcomes regarding TJ effect on cognitive motor [26]. A dual-task design was employed to compare the young and older adults executing specific cognitive tasks while standing [34], walking [35], or in response to postural perturbation [36,37]. It assessed postural control with concurrent cognitive processing. According to the Vergara-Diaz G study, the dual-task gait stride-time variability was sensitive and logical outcome for evaluating the combined cognitive motor was affected by TJ in PD [26]. However, because of the small sample size and high RCT bias in the TJ intervention group of the Vergara-Diaz G study, there was insufficient evidence in our study to support that TJ exercise significantly improved cognitive motor in PD ($p = 0.19$).

Parkinson's Disease Questionnaire 39 (PDQ-39), the Trail Making Test A and B, and Montreal Cognitive Assessment (MoCA) were the often utilized tools in evaluating the global cognitive function. Mini-Mental State Ex-

amination (MMSE) was employed for cognitive screening. MMSE was a comprehensive instrument for detecting cognitive deficits [38]. MMSE exhibited ceiling effects on mild cognitive impairment and floor effects on severe cognitive impairment [39]. MMSE was less sensitive to mild cognitive impairment in PD [40]. K-MMSE performed like MMSE. MoCA was created as a screening tool for mild cognitive impairments (MIC) and was an often used instrument for these investigations [41]. MoCA assessed the executive and visuospatial abilities, memory, language, and attention. The scale's psychometric qualities were sufficient for a quick evaluation of global cognition in PD [42]. Trail Making Test (TMT) was another often used instrument. TMT could be affected by cognitive changes in PD [43]. The 39 items on self-administered PDQ-39 were divided into eight categories, one of which was the cognitive domain [44].

In the present study, it was found that signal intensity of global cognition in PD was improved ($p < 0.05$) by TJ intervention. However, a thorough analysis of these findings was required. There was no agreement on ideal intervention frequency and length because of the heterogeneity of cognitive tests employed in evaluating the global cognitive performance in included trials. This did not change the conclusion that TJ exercises considerably enhanced PD global cognitive function.

4.3 Exercise Prescription

TJ intervention modalities performed more than 3 times a week for 45 to 60 min over at least 12 weeks are preferred in PD patients of short disease duration.

4.4 Limitations

Despite our clarifications of TJ application in PD patients, some issues need further explorations in future experimental protocols. Firstly, which cognitive domains of PD are better enhanced by TJ cannot be accurately judged because of the limitations of current RCTs. Second, there is a need for accurate exercise prescriptions for PD patients of different disease courses. Third, the number of high qualities RCTs is insufficient, and subjective assessment processes may have confounded the results.

5. Conclusions

The findings of this study indicate that TJ affects cognitive function in PD patients. This effect may diminish or become insignificant as a person's disease progresses. The best improvement of cognitive function in PD can be achieved by TJ intervention of 45–60 min twice a week for at least 12 weeks.

Availability of Data and Materials

All data generated or analyzed during this study are included in this published article.

Author Contributions

JY: organization and execution of research project, design and execution of statistical analysis, writing of the first draft of manuscript; YL: organization and execution of research project, design and execution of statistical analysis; WL: conception and organization of research project, review and critique of manuscript; YF: conception of research project, review and critique of manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/j.jin2205123.

Appendix

See Appendix Table 3.

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